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# Proceedings of a Workshop on the Effects of Acid Rain on the Atlantic Salmon Stocks of the Southern Upland Area of Nova Scotia

1-3 March 2000
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Sponsored by
Fisheries and Oceans Canada
Science Branch

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***December 2000***

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## FOREWORD

These Proceedings are a record of the submissions to and discussions at the workshop of March 1-3, 2000, to: assess the effects of acid rain and reduced marine survival on Atlantic salmon stocks of the Southern Upland of Nova Scotia; provide a prognosis for the salmon production capacity of individual rivers impacted by acidification; and to recommend measures to save and enhance the recovery of the remaining salmon and their habitat. The activities and discussions of the meeting, including attendance, summaries, issues and research recommendations for each of the nine papers presented, and minority opinions raised are included in the document. The report records as faithfully as possible the contributions and discussion that transpired at the meeting. However, the individual interpretations and opinions expressed at the meeting are not necessarily scientifically sustainable or supported by other participants. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement has been reached.

## AVANT-PROPOS

Le présent compte rendu relate les discussions et les présentations auxquelles a donné lieu l'atelier tenu du 1er au 3 mars 2000 dans les buts suivants : évaluer les effets des pluies acides et la baisse de la survie en mer des stocks de saumon Atlantique des hautes terres du sud de la Nouvelle-Écosse; établir un pronostic de la capacité de production de saumon des rivières touchées par l'acidification et recommander des mesures pour préserver le saumon restant ainsi que son habitat et favoriser leur rétablissement. Ce compte rendu fait état des activités et des discussions ayant eu lieu; il comprend la liste des participants, des résumés, les sujets traités et les recommandations de recherche associés à chacun des neufs documents de travail soumis et les opinions minoritaires exprimées. Il expose aussi fidèlement que possible les discussions et arguments présentés. Toutefois, les interprétations et opinions exprimées par certains participants ne sont pas nécessairement fondées scientifiquement ou appuyées par les autres participants. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s'il est clairement indiqué qu'elle l'est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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## ABSTRACT

A peer review of the effects of acid rain on the Atlantic salmon stocks of the Southern Upland of Nova Scotia was conducted in the Hayes Boardroom of the Bedford Institute of Oceanography on March 1-3, 2000. The remit was to assess the effects of acid rain and reduced marine survival on Atlantic salmon stocks of the Southern Upland of Nova Scotia; provide a prognosis for the salmon production capacity of individual rivers impacted by acidification; and to recommend measures to save and enhance the recovery of the remaining salmon and their habitat.

Seven working papers and two other presentations based on other scientific papers and documents which had been peer reviewed previously, formed the basis of Habitat Status Report 2000/2E. Forty-seven individuals from the Department of Fisheries and Oceans, Environment Canada, agencies of the Province of Nova Scotia, the Atlantic Salmon Federation, the Nova Scotia Salmon Association, universities, conservation organizations and a public utility participated in the review.

## RÉSUMÉ

On a procédé à un examen par les pairs des effets des pluies acides sur les stocks de saumon atlantique des hautes terres du sud de la Nouvelle-Écosse dans la salle de conférences Hayes de l'Institut océanographique de Bedford du 1er au 3 mars 2000. La demande de renvoi visait à évaluer les effets des pluies acides et la baisse de la survie en mer des stocks de saumon Atlantique des hautes terres du sud de la Nouvelle-Écosse; à établir un pronostic de la capacité de production de saumon des rivières touchées par l'acidification et à recommander des mesures pour préserver le saumon restant ainsi que son habitat et favoriser leur rétablissement.

Sept documents de travail et deux présentations fondées sur des documents de travail qui avaient déjà fait l'objet d'un examen par les pairs ont constitué la base du Rapport sur l'état de l'habitat 2000/2E. Quarante-sept personnes, venant du ministère des Pêches et des Océans, d'Environnement Canada, d'organismes du gouvernement de la Nouvelle-Écosse, de la Fédération du saumon Atlantique, d'universités, d'organismes oeuvrant à la conservation et d'une entreprise de services publics, ont participé à cet examen.

## INTRODUCTION

A peer review of the effects of acid rain on the Atlantic salmon stocks of the Southern Upland of Nova Scotia was conducted in the Hayes Boardroom of the Bedford Institute of Oceanography on March 1-3, 2000. The remit for the review was:

1. Assess the effects of acid rain and reduced marine survival on Atlantic salmon stocks of the Southern Upland of Nova Scotia;
2. Provide a prognosis for the salmon production capacity of individual rivers impacted by acidification; and
3. Recommend measures to save and enhance the recovery of the remaining salmon and their habitat.

The Chairperson, John A. Ritter, welcomed the participants (Appendix I) and the agenda (Appendix II) was then reviewed.

The referees for working papers were:

- Rod Bradford, DFO, Dartmouth, NS
- Carolyn Harvie, DFO, Dartmouth, NS
- Ellen Kenchington, DFO, Dartmouth, NS
- Larry Marshall, DFO, Dartmouth, NS
- Dave Meerburg, DFO, Ottawa, ONT
- John Ritter, DFO, Dartmouth, NS

Management and research recommendations produced at the meeting are listed together under "Recommendations".

## THE REVIEW

**Paper 1 – A brief review of the Canada-wide acid rain strategy for post-2000 (presented by Guy Fenech, Environment Canada)**

Summary

1. The presentation summarized the contents of the following three documents of Environment Canada:
   - Supporting document for The Canada-Wide Acid Rain Strategy for Post-2000, October 1998;
   - 1999 Annual Progress Report on The Canada-Wide Acid Rain Strategy for Post-2000, November 1999; and
   - A review of acid rain science programs in Canada, January 2000.
2. The primary long-term goal of The Strategy is to "meet the environmental threshold of critical loads for acid deposition across Canada". Further sulfur-dioxide (SO2) emission reductions are needed in the southeastern part of Canada and in the mid-western and northeastern United States to solve Canada's acid rain problem. The Canada-Wide Acid Rain Strategy for Post-2000 provides the framework for achieving further emission reductions towards the long-term objective of reducing acid deposition to below critical loads in all parts of Canada while protecting those areas not presently threatened by acid rain.
3. A 75% reduction in SO2 emissions beyond current requirements in the 1990 Clean Air Act Amendments is required to resolve Canada's acid rain problem. The cost of a 75% reduction is $1.6 to 2.1 billion/year in Eastern Canada (Ontario eastwards).
4. 70-75% of wet deposition in Canada is of United States origin. The long-term goal is to meet the environmental threshold of critical loads for acid deposition across Canada.
5. Targets and schedules for emission reductions in southeastern Canada are being negotiated with Ontario, Quebec, New Brunswick and Nova Scotia.
6. The Federal government will maintain an active role in acid rain science and monitoring in cooperation with provincial and territorial governments.
7. Beginning in 1999, governments will report annually on emissions, forecasts and progress.
8. The eastern Canadian provinces and New England acid rain plan calls for further national emission reductions of 50% SO2 and 20-30% Nox beyond current commitments, a public education campaign, and a series of technical data assessments and modelling exercises.

Issues

1. Government departments do not have enough data or resources to ensure the capability to assess both the degree of environmental improvement achieved by emission reductions and the adequacy of the control programs.
2. Would you comment on funding for science work on acid rain? Environment Canada has been carrying much of the "acid rain work load" but its resources are decreasing. A business case was submitted last year for increased funding. This submission was approved in principle and hopefully will result in increased funding support. Other Departments, for

example the Canadian Forestry Service and Quebec Forestry Service, have both been very much involved in coming up with maps of critical loads for soils. In terms of fisheries, the federal Department of Fisheries and Oceans has the most knowledge. Environment Canada, forestry organizations and Fisheries and Oceans are the three most important agencies regarding acid rain work.

3. Has any consideration been given to cost recovery mitigation response from industry? These matters are provincial jurisdiction. Hence, it would be up to the provincial governments to pursue this approach.
4. Why are these provincial issues if the transport of emissions is international? Within a few provinces, industry does support some of the science monitoring and research. In the European Scandanavian countries this is a compensation issue; the Scandanavian model might be a good approach for Canada.
5. Canada is a member of the North Atlantic Salmon Conservation Organization (NASCO treaty), which discusses issues affecting Atlantic salmon. Acid rain was, in the past, discussed regularly, but not since the Clean Air Act was signed. The Habitat Status Report from this meeting will be on the agenda and discussed at the June 2000 meeting of NASCO.
6. Realistic timelines for reductions in acid rain emissions are required in both United States and Canada.
7. Clear identification and prioritization of scientific research deficiencies to combat acid rain are required.

**Paper 2 - The chemistry of precipitation, its effects on river water quality within the area, and prognosis for improvement (presented by Tom Clair, Environment Canada)**

Summary

1. Despite the introduction of significant control measures, acid deposition is still a problem for Nova Scotia waters. The decrease of sulfate (SO4-2) and neutralizing base cations (Cb) in regional waters indicates that the emission reductions are having some impacts. However, pH and acid neutralization capacity (ANC), which are important to aquatic life, are not improving. This leads to the conclusion that critical loads in Nova Scotia are still being exceeded and that more emission cuts are needed for a geochemical equilibrium to re-establish itself within a reasonable time span.
2. Continued monitoring of both acid deposition and the water chemistry of streams and lakes in Nova Scotia are critical to determining if and when changes are occurring in acid rain and its effects on aquatic life.
3. Natural alkalinity is already low in the Southern Upland due to poor cation-generating capacity of the soils and bedrock.
4. Bedrock denudation continues to be overwhelmed by acid deposition even though acid deposition is being reduced. Natural neutralization of Nova Scotia acidic waters is a very slow process.

Issues

1. Are rivers in eastern Canada still being monitored for acidification change? Not by DFO. Environment Canada continues to monitor water chemistry in 15 lakes in Nova Scotia and acid deposition at its monitoring station in Kejimkujik National Park.
2. Is it likely that organic acids might account for some of the trends? Unlikely! Organic acids are diluted the more it rains. Further, overall organic acids contribute only 25-35% of the total acidity of the waters sampled and no trend is apparent.
3. Is Environment Canada doing any research on forestry productivity in Nova Scotia or Eastern Canada? Forestry Canada and University of New Brunswick are doing research.
4. Conclusion has been drawn that because of the imbalance with calcium carbonate there would be no short-term recovery. Accordingly, what are we talking about in terms of time for recovery – decades, half-century, never? It took us 50 years to get into the mess that we are in now; it will probably take another 50 years to recover. The stored sulfates will eventually wash out. Otherwise there is no short-term fix. The most dramatic recovery has been in areas where there is natural buffering capacity.
5. Are we going to have inter-annual fluctuations in pH associated with rainfall, and do we have data on this? Yes, there is significant seasonal variation in pH which is generally associated with seasonal patterns in precipitation.
6. Would you expect to see fewer episodic pH events with reductions in sulfate emissions? Environment Canada is working on this. Specifically, we are working on a model linking frequency and intensity of pH events to precipitation deposition. The problem is that there is so much variability day to day and we are having difficulty developing a model that can handle such high variability. The high variability is an ongoing research concern and a major problem; we have no answer yet.
7. What prognosis do you give to systems with some buffering capacity? Will they continue to flatten out or decrease? The decrease in deposition will cause an increase in pH fairly quickly in these areas. In cation-depleted areas this will take much longer and I would expect recovery to take 50 years or more.
8. What happens when fresh water meets seawater, and when the level of freshwater acidity is high? Is a barrier established at this point of interphase? Simple dilution occurs at this point. Whether migrating fish find this to be a problem is unknown.
9. If the emission rate keeps falling but doesn't hit 0 will the decrease continue? We need to model this effect to determine threshold levels. Is it possible to model such effects by watershed? Yes, and this is the most logical approach.
10. Would foresters lime forests? We would need to ask local foresters. Liming of forests has been done in both the Adirondacks and European Scandanavia.
11. Is it important on a river-by-river basis to know more than just pH response? Yes, cation levels are very important.
12. Regarding critical loads, Nova Scotia stands out as a very sensitive area but is very small geographically in area and population. To what extend is this a problem? Nova Scotia does have an emissions reductions target, and that is very useful. The fact that the target changes in different parts of Canada is difficult to address from a national perspective.
13. Regarding the critical loads for emissions, most of the emissions affecting Nova Scotia are from the eastern USA and central Canada. If critical load reduction targets are achieved in

central Canada, conditions east will improve. If efforts are made to protect Quebec and eastern Ontario, eastern Canada will benefit as well.

14. Regarding the 50-year time frame for recovery, if someone is lake liming, should it be continued for 50 years? Yes, but at a declining rate. If all smokestacks were turned off, recovery would still take 50 years, and if they were not turned off, it would take much longer.
15. Are we going to have to continue gene banking for 50 years? Perhaps!
16. In the forestry industry, does burning provide buffering? Burnoff enhances weathering and produces a pulse of cations. There is a major loss of cations with burnoff.
17. Is it possible to release calcium into the air with emissions? Once industry realizes that they have to do something, they will come up with imaginative solutions to solve the emissions problem. No serious studies have been done to examine where the calcium has disappeared to but there is now less calcium in precipitation. With the reductions and controls on emissions, calcium is not being emitted.
18. Is seasonal variation of pH going to be discussed? The typical seasonal cycle is for pH to be lower in the fall and winter, rising again in late spring and summer, with pulses on the top of the cycle. Seasonal variation in pH needs to be fully described in the final report.

**Paper 3 – Acid toxicity levels in Nova Scotian rivers have not declined in synchrony with the decline in sulfate levels (presented by Walton Watt, formerly of DFO Science)**

Summary

1. Presentation based on paper published in Journal of Water, Air and Pollution, 2000.
2. Water chemistry and fish communities in nine Southern Upland salmon rivers were studied from 1982 to 1996 as part of the effort to monitor the effects of the emission control programs in Canada and the United States. There has been no statistically significant change in total ion content of Southern Upland river water, but there was a significant decline in sulfate levels that was balanced by an increase in organic anions, and declines in calcium and magnesium that were balanced by increases in sodium and potassium. A geochemical scenario is proposed to account for these chemical changes. River water pH levels showed no overall linear trend, but at borderline toxicity sites the year-to-year variations in pH were correlated with changes in juvenile salmon population densities. Ten fish species were collected, but none showed any significant overall time trend in population density. Fish species diversity was positively correlated with pH.

Issues

1. International computer models predict that there should be an increase in alkalinity with a decline in sulfate. This has not been the case in eastern Canadian rivers and the lake data is ambiguous. Is there an existing model we should use? No, existing models are an extreme simplification of the reality of the major factors. For example, they do not take into consideration soils that have no base cations. To date, models have failed to predict anything resembling the water chemistry changes that have occurred in this region.

2. Could activities in the watershed affect input/change in organic acids, such as clearcutting, water temperature? No, not in the watersheds on which I reported. In those watersheds most organic acids come from wetlands which are not usually clearcut.
3. Could the development of roads and miles of ditches expose soil and affect organic acids? This could be a problem if the bedrock is exposed, but could also have the opposite effect if the ditch provides more natural drainage. Could drainage ditches be treated? No, ditches filled with limestone have been tested and shown to be non-effective.
4. Is the virtual loss of salmon returning to the Liscomb River due to increased acid toxicity? The problem on the Liscomb River is higher organic content. Rivers with higher organic content won't realize increases in pH in the near future. Depending upon the pH of the water, organic acids can swing both ways, i.e., for pHs in the 3-6 range.
5. Types of rivers sampled for the study reported in this paper are only a portion of the complex of rivers in Nova Scotia. There is a need to differentiate between the different types of rivers and how their chemistry differs.
6. Has the considerable reforestation of coniferous trees in the province affected organic acids? We don't know, but it is probably not a big factor. Overall we still have a mixed forest in most watersheds, even with hectares of Christmas trees present. The fertilization of Christmas tree farms is probably a benefit.

**Paper 4 - Low pH toxicity effects on Atlantic salmon of Nova Scotia (presented by Gil Farmer, formerly of DFO Science)**

Summary

1. Acid-stressed rivers in Nova Scotia have low concentrations of calcium and high concentrations of dissolved organic matter and total dissolved aluminium. Dissolved organic matter binds to aluminium to form organic aluminium complexes which are not toxic to Atlantic salmon. Increased acidity coupled with the low concentrations of calcium have caused the mortality of salmon in Nova Scotia. Significant mortality (19-71%) of fry occurs at a pH of about 5.0. Mortality of smolts also occurs at a pH of 5.0 but the rate is lower (1-5%). Mortality of parr and smolts is relatively great (72-100%) when pH declines to the 4.6-4.7 range. Mortality of eggs and alevins does not begin until pH declines below 4.8.

Issues

1. Have there been studies to determine whether different strains of salmon have different pH toxicity levels. A paper by Eric Verspoor shows tolerance to low pH to be heritable. However, once pH falls below 5, heritability becomes a moot point.
2. Do threshold mortality levels exist for all life stages? There is not a clear mortality curve for all stages. For instance, it is not known about the delayed mortality on smolts emigrating from acid rivers upon their entry to the salt water. Further information on the effect of low pH on all life stages is required.
3. Is there information on carryover at different life stages to determine whether stress at one stage can effect later stage success? If there is a respite the fish will survive, if not they will

die. For example, pH mitigation measures, such as liming, may have an effect at one stage but not later stages.

4. If fish are released from a hatchery to a river with lower pH, are there more optimum time periods for their release? If pH is less than 5, you should minimize the fishes' exposure to low pH river water by releasing them downriver in the system. There are published papers on this subject of release times/effects. We need to use local data to develop individual river strategies.
5. Does pH shock affect survival? Yes, a published paper on rainbow trout shows that previous exposure to lower pH weakens them and makes them more susceptible to lower pH.
6. What are the implications of the critical load for acid deposition, currently defined as that level at which a pH of 6 would be maintained in 95% of the lakes? Should this definition of critical load be changed considering that reported threshold pH levels for all salmon life stages are considerably lower than a pH of 6? The threshold pH levels for various life stages of Atlantic salmon survival should be further investigated and it may be necessary to re-examine the pH level of 6 as part of the critical load definition
7. How important is calcium to salmon survival? Calcium is very important. An increase in calcium could increase survival even with no change in pH. The calcium issue needs further study.

**Paper 5 – Assessment of the status, vulnerability and prognosis of Atlantic salmon of the Southern Upland of Nova Scotia (presented by Peter Amiro, DFO Science)**

Summary

1. The status of Atlantic salmon populations in rivers of the Southern Upland is critical. The reduction in productive capacity attributed to acidification of the rivers has increased the vulnerability of the salmon populations to low and especially prolonged low marine survival episodes. Analysis indicates that persistence of salmon in the Southern Upland rivers is dependent on the trend of marine survival in the coming years as much as it is dependent on pH.

Issues

1. Is 5% marine survival optimistic? Yes, current survivals are ranging from 2-6%.
2. Are losses due to a hook-and-release angling fishery included in the yield and harvest options presented in your paper. No, they were not included.
3. Is marine survival related to the size of the smolt? Yes, this is a main assumption in the model.
4. For one model ran on the Liscomb River the rate of stocking assumed was double that of the current practice. Was a similar model ran on the LaHave River? No, once the stock was shown to be sustainable, there was no need to increase the level of stocking.
5. Acknowledged that the use of "mean annual pHs" in the analyses presented probably produced an optimistic outlook for stocks.
6. Noted that minimum (or threshold) population limits have not been defined and are required for Atlantic salmon stocks.

7. Noted that the frequency and effects of low pH episodes are unknown and that these were not taken into consideration in the modelling exercises carried out.
8. The Atlantic Salmon Regional Assessment Model (ASRAM), used to develop the projections reported on in this paper, does not reflect the possibility that smolts passing through acid-stressed waters enroute to the sea may be stressed to the extent that they experience increased delayed mortality upon entering the sea.
9. Evidence exists that there are isolated population pockets surviving in acid stressed rivers. Their presence suggests that smolts are passing through acid-stressed waters and surviving to return in order for them to maintain themselves. ASRAM needs to be modified to reflect the passage of smolts through acid-stressed corridors.

**Paper 6 – Precipitation, discharge and temperature variability in Atlantic salmon rivers in acid rain Southern Upland Area of Nova Scotia (presented by Daniel Caissie, DFO Science)**

Summary

1. When pH in a study area is influenced by discharge or the amount of precipation through acid deposition, it is important to understand the variability in such parameters as they ultimately influence mean pH values. Results showed that seasonal pH would be expected to be more variable than the mean annual values based on seasonal variability in both precipitation and discharge. Annually, precipitation and discharge showed similar variability. Discharge showed higher variability seasonally than annually with the coefficient of variation ranging from 30-58% compared to values of below 20% on an annual basis. The summer would show the highest variability in mean pH due to the highest observed variability in mean summer discharge.

Issues

1. Are there any significant relationships between air temperature and pH? Yes, but this can be corrected for.
2. Are there trends in discharge over time? There are no apparent trends in discharge over the long-term, but a decline does seem apparent over the last 10-15 years.
3. Current egg-to-smolt survival rates for salmon are comparable to those reported in the literature. No adverse trend is apparent in the egg-to-smolt survival data to suggest an adverse trend in environmental effects.
4. Can we link stream or river acidification to precipitation? Most definitely! Rain is acidic and thereby lowers stream or river pH.
5. Is forestry activity having an effect on stream pH? Have we lost the buffering capacity we had with a mixed forest? What percentage of a watershed can be cut without effecting runoff? We don't know what intensive forestry practices are doing to the buffering capacity of the soil. We do know that runoff patterns are effected by forest cutting, i.e., faster runoff, higher runoff peaks, more extensive low flow periods.

**Paper 7 – Genetic characterization of the Atlantic salmon stocks of the Southern Upland area of Nova Scotia (presented by Peter Amiro, DFO Science)**

Summary

1. Based on available information there is evidence to suggest that significantly unique populations remain in rivers of the Atlantic coast of Nova Scotia. Extensive stocking programs may have affected these populations. Although molecular genetic data is available for 11 populations, there is uncertainty in the level of differentiation among these populations. Further sampling and analyses are required before proceeding with development of a recovery plan for Southern Upland salmon.

Issues

1. Need recognition that within the Southern Upland we have many ecologically distinct rivers and habitat types. The natural buffering capacity of rivers (i.e., cations) must be taken into consideration in any river categorization scheme.
2. More sampling of Southern Upland rivers is required to determine population structure.
3. Noted that knowledge of historical population abundance and structure is important. There is evidence to suggest that Southern Upland populations were considerably different prior to 1930. It is important to determine if Southern Upland populations have changed over the decades.
4. What is the effect of highly acidic environments on salmon eggs and survivorship? There is selection for pH tolerance.
5. Do time series of scale samples exist for different Southern Upland populations? No, samples are collected only when the opportunity presents itself.
6. On the Medway River there is an opinion that we have two genetically distinct populations; do we have enough samples to determine this? We don't know. We do have sample material (i.e., scales) from both wild Harmony Mills and wild Ponhook fish; it would be interesting to investigate their differences.
7. Need to go through document and remove metapopulation and replace with distinct population. The whole point of SARA is to prevent extinction due to human activities. The exercise of looking for genetic differences in salmon populations is aimed at determining the value of the different river populations from a genetic distinctiveness perspective.
8. In any recovery program, mitigation of acid effects should be done on an individual river basis with priority given to populations confirmed to possess genetic uniqueness. Populations that are not acid-stressed should be conserved at all costs. Populations experiencing low acid-stress are next in priority and will likely require some form of mitigation.

**Paper 8 – A review of the effectiveness and feasibility of alternate liming techniques to mitigate for acid rain effects (presented by Wesley White, formerly of DFO Science)**

Summary

1. It is possible to raise the pH of some acidified salmon habitat enough to ensure the survival of Atlantic salmon by adding sufficient quantities of limestone or other neutralising substance. Limestone is the safest and cheapest substance for liming.
2. Liming headwater lakes has been shown to be an effective technique for liming habitat downstream in rivers where suitable lakes exist in the headwaters. Other methods of liming may also be cost-effective.
3. Dissolution efficiency of limestone from winter lake liming is less efficient than from summer liming, but winter liming may be more cost-effective.

Issues

1. It is a documented fact that liming works, but there is a financial cost which will vary with the physical setting.
2. On a broad scale, liming is not cost effective to reverse the major pH problems of the Southern Upland. Liming could be employed to create refugia, i.e., small scale acid refugia for these rivers to keep pH up in small areas. Limestone gravel has been put in rivers but has had a marginal effect.
3. Important to thoroughly evaluate all liming proposals as to their feasibility and merit. It was noted that we probably don't have all the information required to do a thorough risk assessment.
4. DFO is involved in the approval process for liming projects and could be held liable if liming doesn't work.
5. Would be useful to summarize estimated capital costs for each method of liming.
6. Is it feasible to put lime on the ground in forests? This method has been tried in Scandanavia, but requires much more lime and has had no effect. One problem is that the first lime put on gets inactivated by metals in the soil. It is necessary to add more to have any effect and this is toxic to many wetland plants.
7. British Columbia is delivering fertilizer to lakes by air, could air transport be used here? This method is also being used in Ontario but the cost is high.
8. How many projects are ongoing in the province? There have been several projects initiated throughout the Province of Nova Scotia of which a number are no longer being carried out. Only two of these projects are discussed in the stock assessment reports. Unfortunately there is minimal follow up to such projects to make sure they aren't making things worse.
9. Would you comment on the potential effects of liming projects on downstream water uses? It is true there are other water uses than salmon habitat downstream of liming projects. The potential effects of all liming projects on downstream water uses should be thoroughly considered as part of the approval process. There could be liability if someone else's use is compromised. The review process under the Canadian Environmental Assessment Act (CEAA) should identify potential conflicts of this nature.

**Paper 9 – A review of hatchery stocking practices as effective and feasible mitigation measures for acid rain effects (presented by Trevor Goff, DFO Science)**

Summary

1. There are future roles for hatcheries to play in mitigation of acid-impacted Nova Scotian Southern Upland rivers:
   - live gene banks for genetically unique populations threatened with extirpation;
   - supplemental stocking of threatened populations to prevent further collapse;
   - providing wild parental-origin fish for research on acid impacts;
   - restocking opportunities either from suitable local donor populations or from gene banks following habitat recovery (reduced emissions), or in special circumstances following restoration of habitat by liming; and
   - producing hatchery return fish for harvest or as compensation for harvest.

Issues

1. In assessing the utility of any stocking program it is necessary to consider the loss in production had the fish taken for hatchery broodstock been allowed to spawn naturally.
2. Noted that human intervention in spawning and hatchery rearing of juveniles were a form of artificial selection and might be interpreted as contributing to "domestication" regardless of the generation removed from the wild stock.
3. Noted that it would be more correct to say that there is heritability in age at maturity rather than a specific genetic makeup that yields MSW salmon.
4. Guidelines are required on the numbers of hatchery broodstock that can safely be removed from a population, preferably expressed as a proportion of stock available.
5. Regarding run timing, is there a heritability/genetic control of run timing? Run timing, although influenced by environmental conditions (e.g., low flows), has been shown to be heritable.
6. Past hatchery stockings in Southern Upland rivers could influence the genetic profiles of the recipient stocks. Accordingly, the development of a comprehensive listing of past hatchery releases would be a worthwhile undertaking.
7. The lake liming program on Big LaHave Lake by the LaHave River Association was instituted in good faith that it would lead to an overall increase in salmon production upstream of Morgans Falls and that by the year 2004 there would no longer be a need to lime. It now appears that recovery will be over a much longer time period, and only achieved if significant reductions in emissions are implemented.
8. What is the future role of hatcheries as facilities to house live gene banks? While they offer the potential to house live gene banks, their role as such remains to be defined.
9. Marine survival rates for 2SW x 2SW salmon crosses for the Medway River stocks are lower than for progeny of either 1SW x 2SW or 1SW x 1SW crosses, thereby indicating the importance of the 1SW salmon component in the breeding program to optimize marine survival and actual return to the river.

10. Regarding stocking and pH levels, a guide is required to ensure that juvenile salmon are not stocked in pH-toxic waters.
11. Regarding the potential for stocking to harm the genetic integrity of wild populations, a protocol is required to minimize the risk of such harm. Questions like how many hatchery fish can you safely introduce into a population needs to be addressed, or at what low population level do you refrain from removing adult salmon returns for broodstock.

## RECOMMENDATIONS

Management

1. Priority should be given to support Canada's position to negotiate a further 75% reduction in sulfate emission limits in eastern Canada and the United States to facilitate recovery of Southern Upland salmon.
2. Locally urgent is the requirement to develop a recovery plan for Southern Upland salmon both to prevent further loss of stocks and to hasten their recovery.
3. Protective management measures (e.g., limiting losses to fisheries) are required to prevent further extirpation and will be essential to the success of efforts to effect stock restoration.

Research

The following list of recommended research activities are not prioritized.

1. Require definition of the critical load for sulfate for Atlantic salmon in Eastern Canada and assessment of whether we will be able to achieve a pH of 6, currently one of the main criteria for defining recovery.
2. Documentation is required of the trends in both the amount and chemical composition of precipitation on the Southern Upland (particularly seasonal patterns and changes associated with episodes).
3. Need to re-instate a network of water chemistry monitoring in areas sensitive to acid rain and important to Atlantic salmon production. Monitoring should include the major ions and nutrients and encompass a cross-section of rivers of different chemical types, particularly those with higher organic acid levels because such rivers can be expected to respond differently to reductions in deposition than those that have been monitored previously.
4. Need to develop base cation budgets for individual streams and rivers throughout Nova Scotia and to relate these cation levels to fish survival.
5. A new water chemistry model is required that better reflects regional conditions (namely the absence of base cations in the soil and different organic acid levels).
6. Expose eggs and alevins to pH levels within the 4.0 to 5.0 range to determine rates of mortality. Measurements of pH, dissolved organic carbon (DOC), calcium ($Ca^{++}$) and total aluminium (Al) should be carried out at regular intervals throughout the exposure period which will encompass the green and eyed-egg stages and the alevin stage to terminal yolk re-absorption.

7. Report on the mortality observed among caged salmon parr held in different acidic Nova Scotian rivers (unpublished data, Diadromous Fish Division). Correlate mortality with pH, Ca++ concentration, parr weight and exposure period.
8. The Atlantic Salmon Regional Assessment Model (ASRAM) requires upgrading to improve its predictive capabilities and taking into consideration the current level of knowledge.
9. Conservation requirements for Atlantic salmon need to be defined for the acid-stressed rivers.
10. Further analyses should be undertaken of key variables (e.g., precipitation, air and freshwater temperatures, stream discharge, freshwater pH and egg-to-smolt survival rates) to confirm or reject temporal change in freshwater environmental conditions.

11. Need to conduct a population survey of Southern Upland rivers to verify the rivers in which salmon are present. Coupled with the survey, samples should be collected and analyses carried out to characterize these populations relative to other North American salmon populations and also their uniqueness from each other.
12. Require establishment of a sampling regime and archival system for scale/tissue samples for the future.
13. Require summation of information on hatchery stocking over last 25 years.
14. Research on the application of alternative liming techniques is required to determine the potential application of this mitigative measure in the recovery program for Southern Upland salmon.
15. An assessment model is required to evaluate the effectiveness of different liming practices and proposals. Cost effectiveness is likely to be a major consideration.
16. Require investigation of the potential for post-migration mortality in smolts that have been exposed to sub-lethal acidic conditions before entering the estuary. Length and degree of exposure, and the pH of the water at the hatchery supplying the smolts may influence post-migration mortality.
17. Require research and assessment of alternative stocking practices as mitigative measures for acid-stressed streams and rivers. Four areas identified as warranting investigation include post-migration mortality of acid-stressed smolts, imprinting smolts to limed refuges, releasing smolts far enough upstream to prevent straying to other rivers, and stocking of parr into pH-adjusted lakes.
18. Require the development of protocols and methodology for the application and operation of live gene banks to aid in the preservation of salmon stocks threatened with extirpation.

**Appendix 1.** List of Participants -- Acid Rain Workshop

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## APPENDIX II. Agenda

**PEER REVIEW OF "EFFECTS OF ACID RAIN ON THE ATLANTIC SALMON STOCKS OF THE SOUTHERN UPLAND AREA OF NOVA SCOTIA"**

**MARCH 1-3, 2000**
**Hayes Board Room, Bedford Institute of Oceanography**
**Dartmouth, Nova Scotia**

**(Lead Author and/or Presenter shown in parentheses)**

**Wednesday, March 1**

| | | |
|---|---|---|
| AM | 9:00 – 9:30 | - Introductory Remarks by the Chair (John Ritter) |
| | 9:30 – 10:30 | - A brief review of the Canada-wide acid rain strategy for post-2000 (Guy Fenech) |
| | 10:30 – 10:50 | - Health Break |
| | 10:50 – 12:00 | - Freshwater chemistry acidification trends in sensitive Nova Scotia lakes (Tom Clair) (WP – 2000/10) |
| PM | 12:00 - 1:00 | - Lunch |
| | 1:00 - 2:00 | - Acid toxicity levels in Nova Scotian rivers have not declined in synchrony with the decline in Sulfate levels (Walton Watt) |
| | 2:00 - 3:00 | - Effects of low environmental pH on Atlantic salmon in Nova Scotia (Gil Farmer) (WP - 2000/11) |
| | 3:00 - 3:20 | - Health Break |
| | 3:20 - 5:00 | - Assessment of the status, vulnerability and prognosis of Atlantic salmon of the Southern Upland for Nova Scotia (Peter Amiro) (WP - 2000/12) |

**Thursday, March 2**

| | | |
|---|---|---|
| AM | 8:30 – 9:30 | - Precipitation, discharge and temperature variability in Atlantic salmon rivers in acid rain Southern Upland area of Nova Scotia. (Daniel Caissie) (WP - 2000/13) |
| | 9:30 – 10:30 | - Genetic characterization of the Atlantic salmon stocks of the Southern Upland Area of Nova Scotia (Peter Amiro) (WP - 2000/14) |
| | 10:30 – 10:50 | - Health Break |
| | 10:50 – 12:00 | - A review of the effectiveness and feasibility of alternate liming techniques to mitigate for acid rain effects in Nova Scotia (Wesley White) (WP – 2000/15) |
| PM | 12:00 - 1:00 | - Lunch |
| | 1:00 - 2:00 | - A review of hatchery practices appropriate for mitigating Atlantic salmon losses in acid-impacted rivers (Trevor Goff) (WP – 2000/16) |
| | 2:00 - 5:00 | - Review of the draft Habitat Status Report |

**Friday, March 3**

| | | |
|---|---|---|
| AM | 8:30 - | - Continuation of the review of the draft Habitat Status Report |

## APPENDIX III. Invitation Letter

Fisheries and Oceans / Pêches et Océans

Maritimes Region
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth
NS B2Y 4A2

February 14, 2000

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1» «Address2»
«City», «State»
«PostalCode»

Dear «Title» «LastName»:

You are invited to participate in a Special Workshop to be conducted by the Department of Fisheries and Oceans to scientifically review the "Effects of Acid Rain on the Atlantic salmon stocks of the Southern Uplands Area of Nova Scotia". The Workshop is being carried out as part of our Regional Assessment Process (RAP). Our task is to scientifically review the subject, with the objectives being to provide management advice and recommendations for future research. An Agenda for the Workshop is attached.

The Workshop will take place **March 1-3, 2000**, in the Hayes Board Room at the Bedford Institute of Oceanography, 1 Challenger Drive, Dartmouth, N.S. It will commence at 9:00 a.m. on Wednesday, March 1st. For those of you not familiar with the layout of the Institute, please inquire at the Commissionaire's desk (at the front entrance) for directions.

We are unable to assist you with your travel expenses. However, we hope you are able to attend and would welcome your participation in this important scientific review exercise.

The workshop is open to all who may have an interest in this important subject. So please feel free to pass this invite along to anyone of those individuals.

Sincerely yours,

John A. Ritter, Manager
Diadromous Fish Division

Attachment

Canada

**APPENDIX IV.** List of Documents Tabled (including authors)

Amiro, P.G. 2000. Assessment of the status, vulnerability and prognosis for Atlantic salmon stocks of the Southern Upland of Nova Scotia. DFO Can. Stock Assess Sec. Working Paper 2000/12.

Amiro, P.G., and M.W. Jones. 2000. Genetic characterization of the Atlantic salmon stocks of the Southern Upland area of Nova Scotia. DFO Can. Stock Assess Sec. Working Paper 2000/14.

Anon. 1999. 1999 Annual progress report on "The Canada-wide acid rain strategy for post-2000". Prepared by the Acid Rain Task Force of the Federal/Provincial/Territorial Ministers of Energy and Environment. 12p.

Anon. 1998. "The Canada-wide acid rain strategy for post-2000: Strategy and supporting document". Prepared by the Task Force of the Federal/Provincial/Territorial Ministers of Energy and Environment. 11p.

Caissie, D. 2000. Precipitation, discharge and temperature variability in Atlantic salmon rivers in acid rain Southern Upland Area of Nova Scotia. DFO Can. Stock Assess Sec. Working Paper 2000/13.

Clair, T.A., J.M. Ehrman, and C-U. Ro. 2000. Freshwater chemistry acidification trends in sensitive Nova Scotia lakes: 1983-1997. DFO Can. Stock Assess Sec. Working Paper 2000/10.

Farmer, G.J. 2000. Effects of low environmental pH on Atlantic salmon in Nova Scotia. 2000. DFO Can. Stock Assess Sec. Working Paper 2000/11.

Fenech, G. [Chair], J. Dupont, M. Hingston, R. Hughes, K.R. Foster, and P.K. Misra. 2000. A review of the acid rain science programs in Canada - a report prepared to meet the requirements of "The Canada-Wide Acid Rain Strategy for Post-2000". 54p.

Goff, T.R., L. Anderson, S. Ratelle, and D. Sutherland. 2000. A review of hatchery practices appropriate for mitigating Atlantic salmon losses in acid-impacted rivers. DFO Can. Stock Assess Sec. Working Paper 2000/16.

Watt, W.D., C.D. Scott, P.J. Zamora, and W.J. White. 2000. Acid toxicity levels in Nova Scotian rivers have not declined in synchrony with the decline in sulfate levels. Water, Air and Soil Pollution. 118: 203-229.

White, W. 2000. A review of the effectiveness and feasibility of alternate liming techniques to mitigate for acid rain effects in Nova Scotia. DFO Stock Assess Sec. Working Paper 2000/15.